MULTISCALE METHODS FOR MATERIAL FAILURE SIMULATIONS

by

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ABSTRACT

The objective of this thesis is to develop multiscale methods for material failure simulations. Three major topics are covered in this thesis: (i) mathematical homogenization method for geometrically nonlinear problems; (ii) adaptive two-scale nonlinear homogenization method; and (iii) reduced order superposition finite element method.

In the first topic, the classical mathematical homogenization theory is generalized to account for finite unit cell distortions of heterogeneous medium subjected to transient loading. An auxiliary macro-deformed configuration, where the overall Cauchy stress is defined, and mixed unit cell boundary conditions for modeling nonperiodic boundary deformation are introduced and verified. The method is implemented in ABAQUS and verified against direct finite element simulations.

To reduce the computational cost of direct homogenization method, an adaptive two-scale nonlinear homogenization method is developed in the second topic. The adaptive two-scale homogenization procedure combines a reduced order homogenization method and a direct mathematical homogenization method. A simple strain-based indicator is used to guide the construction of a nearly optimal model consisting of either a direct or a reduced order unit cell model. Consistent interscale transfer operators are developed to map the information between the two homogenization models. The method has been verified and validated.

Finally, a reduced order superposition finite element method is developed based on the partition of unit method and the s-version of the finite element method. The degrees of freedom of the superposition method are reduced by projecting the lowest eigenmodes (excluding rigid body) of the superimposed fine mesh to the underlying coarse mesh. A simplified energy-based element erosion criterion is introduced to alleviate mesh size-dependency for material failure simulations. The method has been integrated in ABAQUS, and the failure criterion has been verified numerically.